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High density plasmas and new diagnostics: an overview

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Since 2005 some unexpected issues have come to the attention of the ECRIS community, making questionable the dependence of the output currents and charge states only on macroscopic plasma parameters (density and temperature); plasma instabilities, local fluctuations and/or non uniform distribution of the plasma density, non linear response of the electron heating to the pumping wave frequency, or sensitivity to slight adjustments of the operating frequency and of the magnetic field, have been correlated with the intensity and emittance of the plasma-generated beams, showing that the parameters' space has not been fully explored, as well as the wave-to-plasma interaction in a closed resonant cavity (i.e. the ECRIS plasma chamber).

One of the most relevant limiting factors for the full understanding of ECRIS fundamental mechanisms consists in the few types of diagnostics tools so far designed and installed on such compact machines. Microwave-to-plasma coupling optimisation, including new methods of density overboost provided by plasma waves generation, as well as magnetostatic field tailoring for generating a proper electron energy distribution function, suitable for optimal ion beams formation, will require diagnostics tools spanning across the entire electromagnetic spectrum: from microwave interferometry to X-ray spectroscopy; these methods can be implemented in advanced forms including high resolution X-ray spectroscopy and spatially-resolved X-ray spectroscopy made by quasi-optical methods (pin-hole camearas). The ion confinement optimisation also requires a complete control of cold electrons displacement, which can be performed by optical emission spectroscopy (for X-ray and optical spectroscopy).

Several diagnostics tools have been recently developed at INFN-LNS, including "volume-integrated" X-ray spectroscopy in low energy domain (2-30 keV, by using SDD detectors) or highly energetic regimes (>30 keV, by using HpGe detectors). For the direct detection of the spatially-resolved spectral distribution of X-rays produced by the electronic motion, a "pin-hole camera" has been developed also taking profit from previous experiences in the ECRIS field.

The paper will give an overview of INFN-LNS strategy in terms of new microwave-to-plasma coupling schemes and advanced diagnostics supporting the design and construction of new ion sources and/or for optimizing the performances of the existing ones, with the goal of a microwave-absorption-optimization oriented design of future machines.